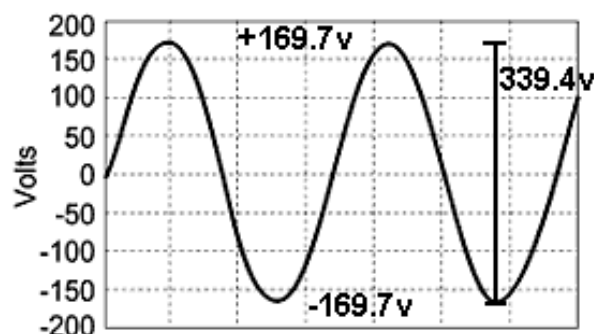# The Amateur in You, Part 2

What have you been pondering?

RMS

In the US, we say that our standard household wall socket voltage is 120 VAC (volts alternating current). Yet, if you were to look at its waveform on an oscilloscope, which displays a measurement of an electrical signal, it looks like anything *but* 120 volts:

The RMS (root-mean-square) value of an electrical quantity (voltage, current, power) came about through the desire to understand the *net effect* that quantity has on a load (the device or circuit that requires the energy). Calculating the *average* of an AC voltage to determine the net effect would not be very useful, because from the above graph it's apparent that the average voltage is zero volts, since it's negative for as long as it's positive.

Yet, when I stick my fingers in the light socket, it certainly doesn't feel like zero volts. In fact, this "feel like" effect is what we're after, and can be observed or measured in *the amount of heat* my finger might feel. So, the question becomes, **What steady (DC) voltage will provide the same net heat effect in a load as a given AC peak voltage?**

Heat is a quantity of *energy*, and the amount of heat or energy over a certain amount of time is known as *power*. Power is useful because it tells me not just how many buckets of heat are being dumped into my finger, but how fast my finger is burning up.

For example, if I poured a cup of boiling water on my hand all at once, I will probably get badly burned. But if I poured that same cup of boiling water on my hand, a hundredth of a drop at a time, over the course of a week, my hand will likely survive the hot bath. The amount of heat energy was the same in both cups, but the longer time all that energy hit my hand means my hand was exposed to much lower power, and so I felt it less.

Therefore, answering our question requires determining the amount of power (heat per time) the AC signal is being dissipated in a load, and calculating the equivalent DC voltage that would result in the same power (heat per time) dissipation. The following equation is that very calculation for voltages:

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2(t)\,dt}$$

Because the given AC voltage is any function *v(t)*, this equation accounts for any kind of AC waveform, not just sinusoidal, which is what appears at our light sockets. For the common *sinusoidal case*, this entire RMS calculation simplifies to

$$V_{\mathrm{RMS}} = \frac{V_{\mathrm{p}}}{\sqrt{2}}$$

So, for a peak voltage (from the above graph) of 169.7 volts, what shows up at the wall outlet is (169.7 volts / 1.414) ≈ **120 VAC**$_{\mathrm{RMS}}$.

Much (not all!) of our concern for energy consumption and **power transfer is calculated based on RMS values**. This includes transformers and RF transmission.

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